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Mapping the future of micromotors

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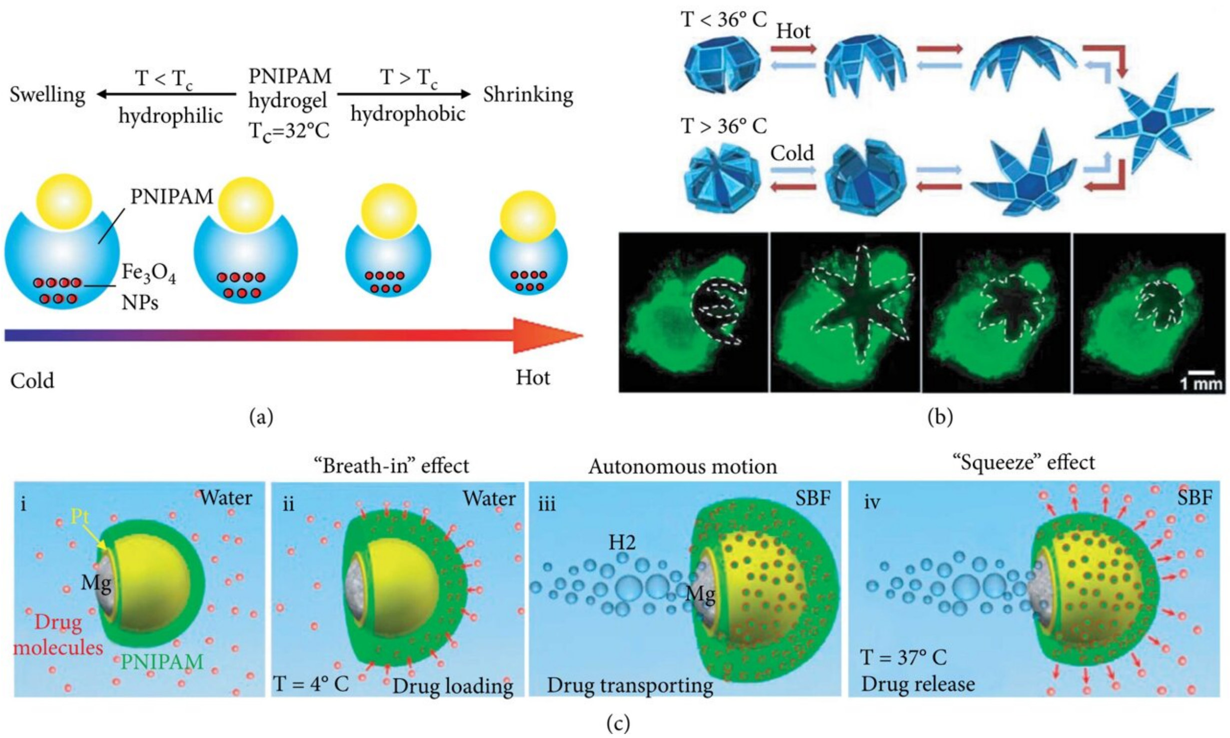

Representative hydrogel-based thermo-responsive micromotors. (a) A microgripper shrank and grasped the cargo when the temperature was above LCST. (b) Schematic image of a thermo-responsive microgripper exhibiting reversible self-folding and unfolding architectures (top); application of a thermo-responsive microgripper in capturing and excising cells from a live cell fibroblast clump (below). Reproduced with permission from ref [50]. Copyright 2015 American Chemical Society. (c) A schematic image of an Mg/Pt-PNIPAM Janus micromotor demonstrating the process of drug loading, transporting, and releasing behaviors. Credit: *Cyborg and Bionic Systems* (2022). DOI: 10.34133/2022/9852853

It's the stuff of cartoons and movies: a team of scientists shrinks down and flies a ship the size of a blood vessel through tissue and sinew to the site of injury or disease. They directly repair or attack the site—whatever is needed—without disturbing surrounding tissue. When the job is done, the patient gives a mighty sneeze and out pops the team, problem solved.

The science fiction is closer to reality than we realize. Not miniaturizing people, of course, but researchers across disciplines have engineered tiny machinery capable of a variety of biomedical tasks to help precisely assess and treat various ailments—in the lab. The question now is how to translate the work from lab benches to hospital beds. A research team based in China reviewed the current state of micromotors for biomedical applications and proposed the next steps to advance the work.

They published their recommendations on Oct. 10 in *Cyborg and Bionic Systems*.

"The field of medical micromotors has been rapidly developing and hold great promise for executing diverse medical tasks such as targeted drug delivery, precision cell microsurgery, micro/nanomanipulation, and noninvasive/minimally invasive diagnosis and therapy," said co-corresponding author Jinhua Li, professor in the School of Medical Technology, Beijing Institute of Technology.

"In this review paper, we set out to provide a better understanding of the design, fabrication, and future directions of hydrogel-based micro- and nanomotors with active stimuli responsiveness for diverse biomedical applications."

A medical micromotor's functionality primarily depends on the material with which it is designed, according to Li.

"Hydrogels are very suitable for fabricating medical micromotors because they have many advantages, such as porous network structures and responsiveness to multiple stimuli," Li said. Hydrogels are insoluble but can absorb water while still maintaining structural support. "The integration of stimuli-responsive hydrogel materials into the design of medical micromotors can endow them with new favorable features, such as morphing, biocompatibility and biodegradability, and controlled drug loading and release ability."

In laboratory settings, micromotors made with hydrogels can hold or tow therapeutic agents —including drug-loaded particles and cells—to a tumor or other diseased site for release. If they are designed to respond to specific stimuli, such as pH levels or external signals, they can also conduct specific medical tasks, like cell sampling and clot removal.

One major problem with this, though, Li said, is that the fabrication materials used to achieve such micro-sized object manipulation often comprise biologically incompatible or nondegradable components that can cause undesirable physiological effects.

"Micromotors need programmable fabrication techniques and maneuverability with more degrees of freedom, as well as more sophisticated shape-morphing capacities, with more complicated microarchitectures, to unlock more locomotion and object manipulation modes," Li said.

Li and the team also called for more research in three specific areas: the time it takes a micromotor to swell or contract as needed, a key performance metric for the service life of the device; what foreign stimulus signals can be used to trigger micromotor action without causing harm to the patient undergoing treatment; and more extensive experiments to best understand how to manipulate and navigate micromotors in the living environment with the help of clinical tools and imaging systems.

"The research area of hydrogel-based stimuli-responsive micromotors for multiple biomedical applications remains in its infancy," Li said.

"With more and more in vivo studies, these micromotors have huge translation potential for various medical application scenarios. Researchers, pharmacists, engineers, physicians, and experts in other areas should work together to advance fabrication, programmable shape morphing, stimuli responsiveness design, and in vivo experiments of hydrogel-based micromotors to finally achieve their clinical translation and applications."

More information: Huaijuan Zhou et al, Hydrogel-Based Stimuli-Responsive Micromotors for Biomedicine, *Cyborg and Bionic Systems* (2022). DOI: 10.34133/2022/9852853

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